Topic

2

Modeling Hot and Cold Planets

Activity A   **Modeling Hot and Cold Planets**

Activity B   **Experimenting with Computer Models**

Activity C   **Approximating the Average Surface**
(optional)   **Temperature of the Earth**

Considering a Real World Problem

Preparing for Mars Living in an Arctic Outpost

One of NASA's long-term goals is to create a human habitat on Mars. Interest in this mission has lead to a funded project to construct an experimental facility on Earth where scientists and engineers can develop and test technical and human capabilities to live on a Mars outpost.

This mission is a project of the Mars Society. One of the first challenges was to identify a location on Earth that resembled the environmental conditions on Mars as a site for the habitat. Haughton Crater on Devon Island, Nunavut, Canada was selected.

Figure 2.1. Painting of the Mars Flashline Arctic Research Station.

The Mars-like geologic features and extreme cold temperatures make Haughton Crater a good Earth locale to test an experimental facility for an extended human mission to Mars. For more information on Haughton Crater and the habitat, visit the Mars Society web site (http://arctic.marssociety.org/devon.html).

The Problem

By the time you complete the activities in this section, you will have identified and prioritized several factors needed to produce a habitable climate. These preliminary ideas can be applied to the Mars Society project to help design and construct the Flashline Research Station.

Do you agree that Haughton Crater is the best Earth location for an experimental Mars human habitat? What geologic and atmospheric conditions exist on Devon Island that may have lead to the decision to construct the facility there?

If you were a researcher on the science and engineering team designing and constructing this facility, what conditions would you have to set to allow humans to adapt to this environment and live in the habitat. Quantify your responses to this question as best as you can.

What materials would you use to construct the habitat in order to compensate for the extreme temperature conditions? How would your design produce habitable conditions for researchers to spend long periods of time at the facility? What other mission considerations are there for human habitability?

Activity A

Modeling Hot and Cold Planets

Overview

Studying why extreme temperature differences exist between Earth and other planets in our solar system most similar to our planet presents a unique challenge to scientists. How can they conduct experiments with these large planetary bodies to learn about how they work? Which variables are most important in controlling and altering temperature? How do these variables interact within the whole planetary system to produce either the habitable temperature of Earth or the inhospitable temperatures of Mars and Venus?

One approach to this study is to design and construct physical models that simulate specific physical or chemical processes. With these small-scale models, researchers can conduct experiments to learn about how a much larger system works.

Teams will design experiments to test any one of the factors identified in their Knowledge Map (created in a previous activity) to determine if that factor could be responsible for the magnitude of the temperature differences. You will be limited to using available supplies, therefore you may not be able to investigate all of the factors.

Figure 2.2. Setup of the experiment.

Each team should divide into two sub-teams. Each sub-team will be responsible for completing half of the experiment. One sub-team should try to produce the highest temperature possible (Venus-like conditions) and the other sub-team will try to produce the lowest temperature possible (Mars-like conditions).

One of the materials, a light source, should remain at a constant height throughout the experiment. Both parts of the experiment should be run simultaneously in order to save time.

When the investigation is complete, all teams will convene to discuss which of the variables has the greatest effect on the temperature and habitability of a planet's surface.

Learning Objectives

✓ Design an experiment to answer a specific question and test a hypothesis.
✓ Differentiate independent and dependent variables.
✓ Evaluate the results and suggest modifications to an experiment.
✓ Prepare a synthesis of experimental results to prioritize a set of parameters.
✓ Explain a conceptual relationship among temperature, energy inputs, and surface features.
✓ Describe strengths and limitations of physical models.

Relevance

People around the globe are concerned with current events and the impact these events have on their daily lives. They are also interested in how these current events will affect future lives and generations. This is especially true for events that impact upon our shared habitat, the Earth system. In order to make predictions about how such a complicated system may develop in the future, we have to develop models. Models enable us to improve what we know about the relative importance and interconnection of specific factors or variables, so that we can better understand the delicate balance that regulates Earth's habitable temperature.

Modeling Hot and Cold Planets

Materials

2 small plastic containers (to hold the models)
2 light sources (150 Watt light bulbs)
2 digital thermometers per team
Various colors of aquarium gravel
Various colors of modeling clay
Water
Sand
Rolls of cotton
Transparency sheets
Rolls of clear plastic wrap
Bag of aquarium moss

Methods

Preliminary Discussion and Planning

1. Examine your Knowledge Map (Topic 1, Activity A) and develop a hypothesis to describe the factor that has the greatest effect in producing a planet's habitable temperature.
2. Challenge: design a physical model of one hot and one cold planet each, using materials available to you in the classroom.
3. Competition: design an experiment that achieves the greatest temperature difference between these two physical models.
4. Organize into investigative teams of about five students and determine the role of each team member. Complete and submit the Investigation sheet: Team Members.

Experimental Design

1. Prepare your team's research proposal by completing and submitting the Experimental Design Proposal.
2. Prepare the experimental plan by completing and submitting the Methodology for a Controlled Experiment.

Experimentation and Observation

1. Set up the experiment based on your Experimental Design Proposal.
2. Each team should follow a common protocol by taking temperature measurements of their hot and cold planet model every minute for a 20 minute period.
3. Record your measurements on the Data Sheet: Modeling Hot and Cold Planets.

4. A second round of experiments may be conducted. After the results are analyzed and discussed and if the researchers determine that modifications can be made to their experiment to achieve a greater temperature difference between the two models, repeat the steps for data collection and analysis.

Data Analysis, Comparisons, and Consensus

1. Review the data your team collected for both models.
2. Analyze the temperature data by completing the Experimental Results Data Sheet.
3. Coordinate your team's presentation to the class.
4. Contribute to the class discussion of results. Based on this discussion, fill in the Investigative Team Consensus and the Priority of Experimental Parameters.
5. Answer all the Questions at the conclusion of the experiments and data analysis. This is an individual assessment of what you learned in the modeling experiments. All responses should be shared among the team to gain a collective understanding of the experimental results of modeling hot and cold planets.
6. Read and discuss the Reference: Mathematical Models.

Investigation Notebook

1. Investigation: Team Members
2. Investigation: Experimental Design Proposal
3. Investigation: Methodology for a Controlled Experiment
4. Data Sheet: Modeling Hot and Cold Planets
5. Data Sheet: Experimental Results
6. Data Sheet: Investigative Team Consensus
7. Data Sheet: Priority of Experimental Parameters
8. Questions: Modeling Hot and Cold Planets
9. Essay: Modeling Hot and Cold Planets

Team Members

Before planning and carrying out your experiment, you must first decide who will serve each role on your research team. Look over the responsibilities listed below and decide who will take on each position:

Lead Researcher _____

Responsibilities:
- Organize activities of your team.
- Make sure that all members are contributing productively.
- Criticize the results of your experiments.
- Make suggestions to improve your experimental procedure.
- Initiate the repetition of an experiment if necessary.
- Keep notes on the following:
    1. How could your experimental procedure be improved?
    2. What materials do you lack in order to make this a more effective experiment?

Materials and Data Managers

Hot Planet	**Cold Planet**

Responsibilities:
- Acquire materials for setting up the experiment.
- Coordinate team effort to set up the experimental model.
- Keep organized records of all experimental measurements.
- Collect, organize, and return all equipment at the end of class period.
- Organize all written material for your group and submit at the end of the class period.

Experimental Communication

Hot Planet	**Cold Planet**

Responsibilities:
- Carefully note all the steps of experimental procedures.
- Construct diagrams of the experimental set-up.
- Construct graphs of the experimental results.
- Coordinate the team presentation of the results and analysis.

Experimental Design Proposal

Before getting into the details of your experiment, propose a hypothesis and realize the limitations of your experiment. Be sure to review your hypothesis and limitations with your instructor.

Hypothesis

How do you expect changing your selected habitability factor to affect the surface temperature of your model systems? Your selected factor should be the variable you consider to have the greatest effect in producing a habitable temperature.

Experimental Limitations

How do the materials used in this experiment differ from the objects they are simulating?

How does your energy source differ from the object that it simulates? Is it the only source of energy present?

Experimental Expectations

How large a temperature difference are you expecting between your models?

Methodology for a Controlled Experiment

Design an experiment to determine if the habitability factor you have selected could account for the magnitude of difference in the surface temperatures of a cold (Mars-like) and a hot (Venus-like) planet. Your group should be divided into two sub-teams. One team should model high temperature conditions, the other low temperature conditions. Discuss the questions on the next page before carrying out your experiment. Wait until your experiment is in progress to fill in your answers. Be sure to review your methodology with your instructor.

Laboratory Materials	Simulated Object
Light source	Sun
Plastic cup	Planet
Gravel, water, clay, sand, other textured materials	Surface of the planet
Additional Materials	
Meter sticks, thermometers	

Experimental Procedure

Indicate the steps you plan to take in order to conduct your experiment.

Analysis of Experimental Variables

Variables
List all the materials you can change during an experiment.

Independent Variable
Which variable can the experimenter purposely change?

Dependent Variable
Which variable will respond to the change in the independent variable?

Experimental Controls
Which factors will not change during the experiment?

Modeling Hot and Cold Planets

Record your data (once per minute for 20 minutes) in the table below. Report the temperature at 20 minutes and your estimated final temperature. The columns under "Round Two" should only be used if researchers decide to modify their experiments and repeat the procedure.

Time (minute)	Round One		Round Two	
	Hot Planet	Cold Planet	Hot Planet	Cold Planet
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				

Table 2.1. Observed Temperatures of Modeled Hot and Cold Planets.

Experimental Results

Report your experimental results based on the data you collected for the hot and cold planet models. First, note the temperature conditions achieved by both models. Next, plot your data and extrapolate your final temperature for the two models. Compare these preliminary results and explain what you have learned about your original hypothesis.

Independent Variable: _____

Dependent Variable: _____

### High Surface Temperature Planet (Venus-like) Conditions

Describe your high temperature planet experimental conditions.

Low Surface Temperature Planet (Mars-like) Conditions

Describe your low temperature planet experimental conditions.

Graph Data

Graph your data and extrapolate your final temperature. Write a caption below your graph to describe how these conditions compared with your original hypothesis.

Temperature

Time
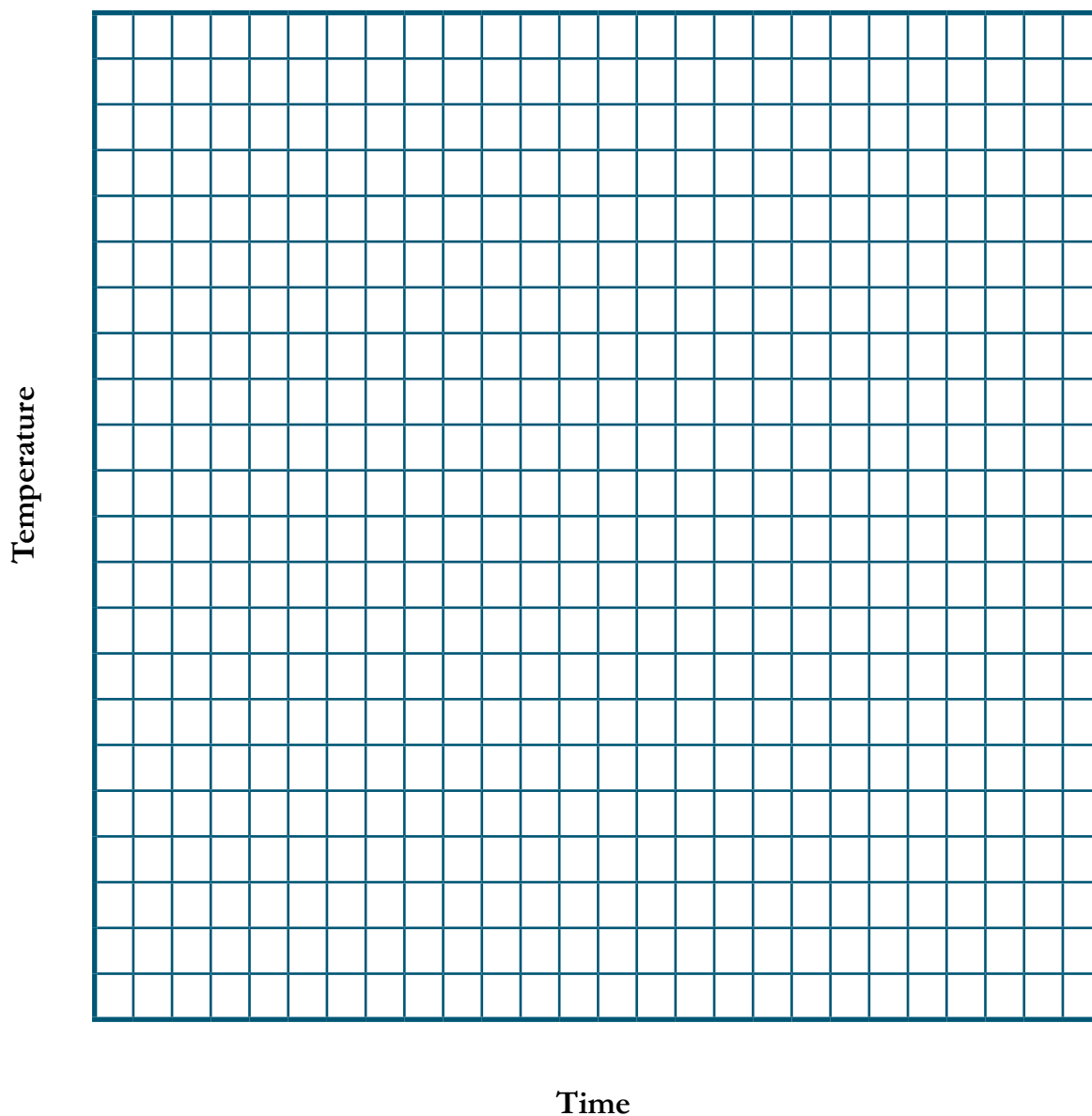
Caption:

If you were to repeat the experiment, what changes could you implement to make the magnitude of the difference in surface temperature closer to what you expected?

Investigative Team Consensus

After all the teams complete the experiments and analyze their results, reconvene to discuss your findings. Try to determine the most effective way of changing the temperature of a planet. Students responsible for Experimental Communication will lead their team's presentation, summarizing their findings. These findings should be placed in a table on the board, similar to the table below. Fill in your copy of the table with results of the various teams as they are written on the board.

Summary of all Teams' Results

Team	Experimental Parameters	Hot Planet Temperature	Cold Planet Temperature	ΔT	ΔT/Time

Table 2.2. All Teams' Results.

Priority of Experimental Parameters

The teams work together to list the various parameters used in order of their effectiveness in influencing the temperature of the model planet. Begin with the most effective and end with the least effective:

**Most Effective** 1.

2.

3.

4.

5.

Least Effective 6.

Modeling Hot and Cold Planets

1. You have been asked to help design a house in the desert. What color window shades would provide the coolest temperatures inside the house?

        a) white   b) black

        c) green   d) yellow

2. If we were able to remove all the clouds from Venus, how would the surface temperature of the planet change?

        a) It would increase

        b) it would decrease

        c) no change would be noticeable

        d) the temperatures would first increase and then return to the original temperature.

3. The following diagrams represent four parking lots in New York City. With all other factors being equal, which of these lots would have the highest daytime temperature?
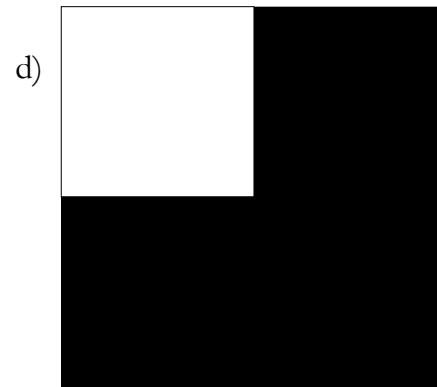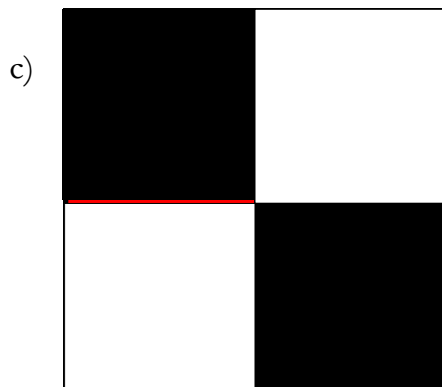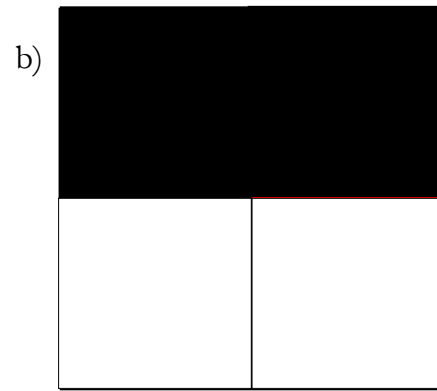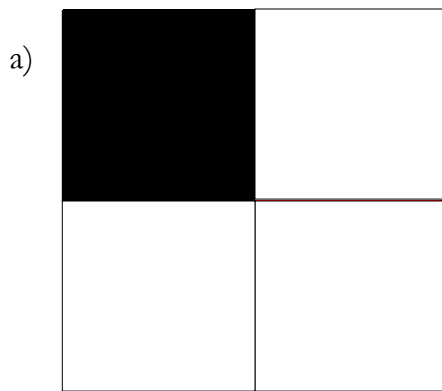
4. A student wants to know how changing the material of a surface affects the temperature of the surface. She performs identical experiments, each time only changing the material. She uses sand, cement, glass, ice, polished aluminum, dry soil, and soil with grass. In each case, she places the surface 50 cm below a 250 Watt light source and measures the temperature of the surface every 30 seconds for 10 minutes. She records the results in a data table in her notebook.

Which of these factors is the independent variable in her experiment?

    a) the light source   b) the type of material
    c) the temperature   d) the time taken

5. A student prepares four different models of planets using small plastic cups to represent the planets. The four models are constructed from different materials and placed at different distances from different light sources. The descriptions of the models appear in the table below.

Which two models could be used to determine the effect of a single factor on the model temperature?

    a) I and II   b) II and III
    c) III and IV   d) I and III

Model	Light Source	Distance	Material
I	250 W	20 cm	Red Clay
II	100 W	20 cm	Green Gravel
III	250 W	50 cm	Red Clay
IV	100 W	50 cm	Red Gravel

Modeling Hot and Cold Planets

During the planning of NASA's Apollo missions that took humans to the moon, the design engineers had to ensure that the habitability of the spacecraft would be maintained throughout the week-long mission. Based on the concepts you have learned in this activity, what would you expect were some of the features incorporated into the spacecraft's design so that a comfortable temperature was maintained? Explain each of your choices. If necessary, use an extra sheet of paper.

Mathematical Models

Your attempts to create physical models of cold and warm planets were hampered by several problems and limitations. You used small plastic containers with only one or two types of surface. Measurements could only be taken for 20 minutes. The room was probably already warmed or cooled by a radiator or an air conditioner. You managed, however, to obtain results that appear qualitatively correct; brighter surfaces were generally colder and bringing the light source closer to the model increased the surface temperature.

This happens because physical phenomena follow basic laws of physics. If we now wanted to study those same phenomena and reduce the limitations of physical models, we could insert those basic laws of physics in the form of equations into a mathematical model and run it on a computer. This is exactly what you will do in the following activity – simulate the physical model experiments using a computer model. This first use of a computer model is just to whet your appetite. In the next topic you will follow a step-by-step process to build a computer model yourselves and to understand how such models can be used to study different systems.
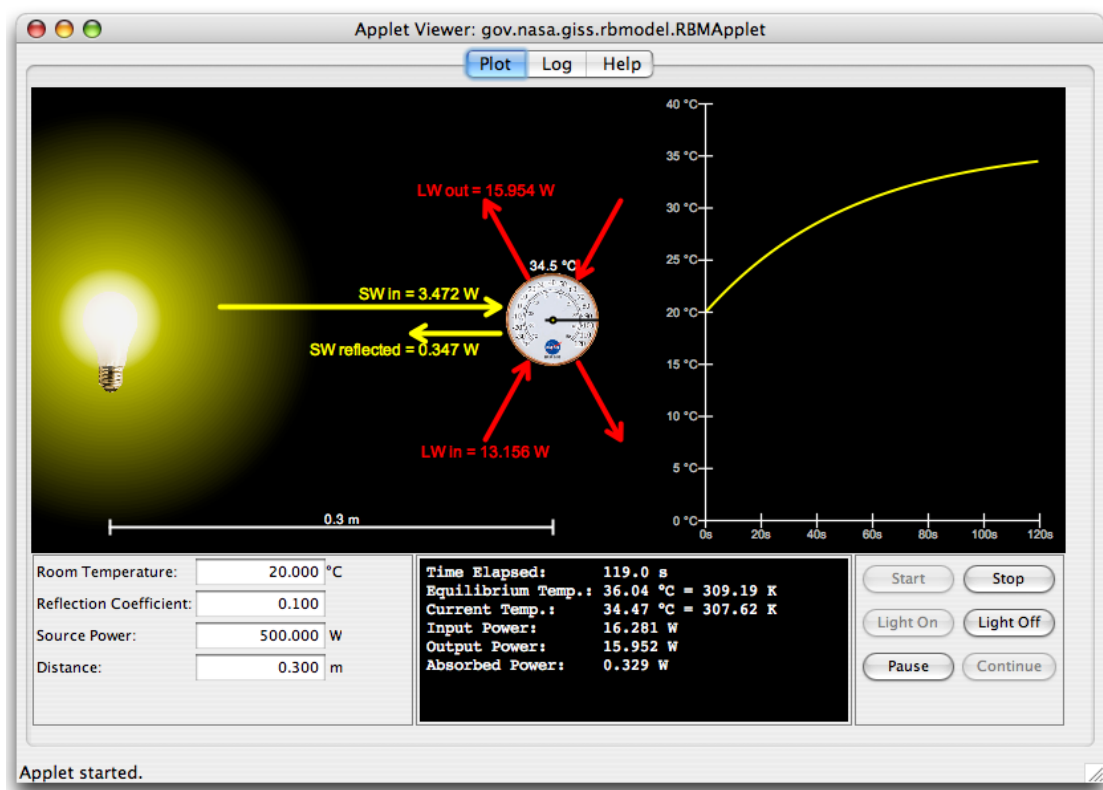

Figure 2.3. An experiment in progress using the Local Radiation Balance Computer Model.

Experimenting with Computer Models

Overview

The Local Radiation Balance Computer Model is available for your investigative team to run an experiment similar to the hot and cold planet physical model studies performed in the previous activity. Specifically, your team can run an experiment to see what happens when the room temperature is changed or when the "lights are kept on" for a continuous period of time. Several other experiments are possible with this computer model. By experimenting with the Local Radiation Balance Model, investigative teams will be able to assess how computer models can be used to understand factors that influence a planet's temperature.
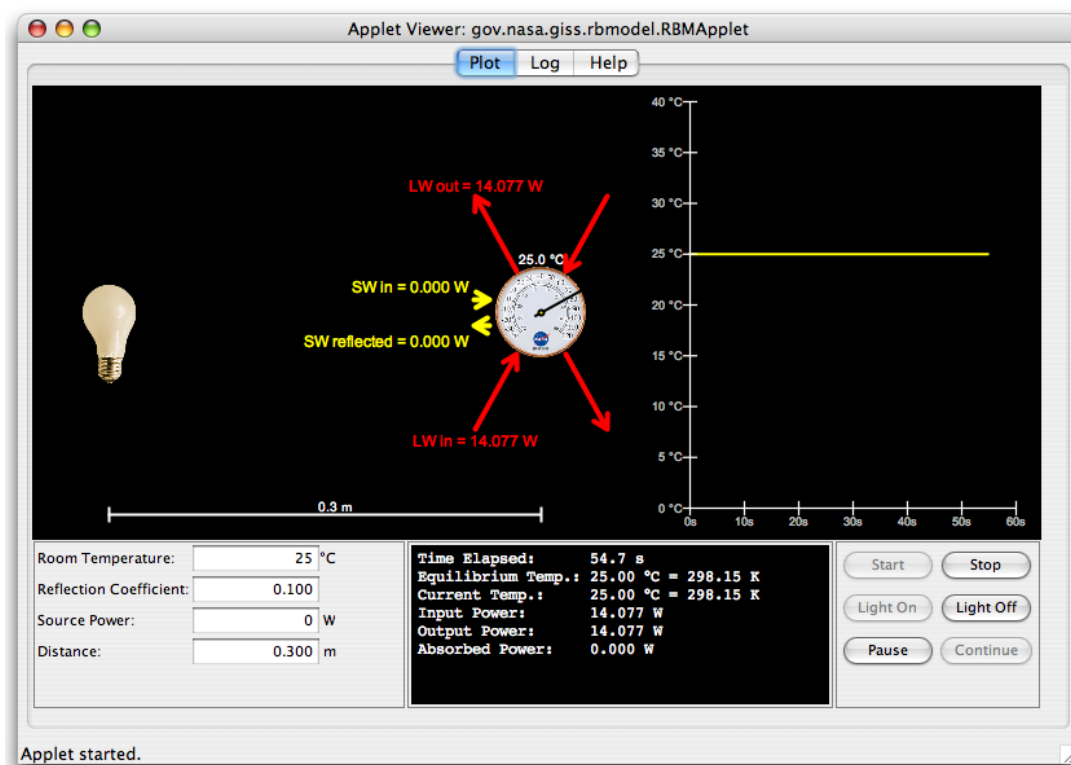
Figure 2.4. Screen shot of the Local Radiation Balance Computer Model. No energy is emitted from the source, during this experimental run, resulting in a constant temperature for the objet.

Work in teams of two or three students per computer to conduct two computer modeling experiments. By applying a methodology similar to the hot and cold planet physical models experiment, use the computer model to study the variables that influence temperature.

In the first experiment, the effect of distance from an energy source on temperature is investigated. A similar experiment can also be performed to investigate the effect of the power of the energy source on temperature.

Student Activities

In the second experiment, the effect of the surface features or reflectivity of an object on its temperature is studied.

Your aim in both experiments is to assess the importance of these variables on planetary temperature, as well as understand relationships between variables and the associated processes at work in the earth system.

Learning Objectives

- ✓ Describe an equilibrium temperature.
- ✓ Identify the factors leading to an equilibrium temperature.
- ✓ Relate the temperature of an object to the energy it emits.
- ✓ Relate the temperature of an object to the reflectivity of its surface.
- ✓ Identify major energy inputs and outputs of a system.
- ✓ State and apply the Law of Conservation of Energy.
- ✓ Qualitatively relate 'distance from the source' to the 'energy incident upon an object.'
- ✓ Describe relative strengths and limitations of physical and computer models.

Relevance

Mathematical computer models capable of simulating earth system processes enable researchers to conduct experiments that would be difficult, if not impossible, to implement on our planet. To understand the complex earth system, where changes occur due to so many natural and human processes, researchers must work with observations from the real world and results from computer modeling experiments. As research tools, mathematical models that run on computers give a researcher an opportunity to ask a range of "What if…" questions to try and discover how processes work in the earth system and how they may change in the future.
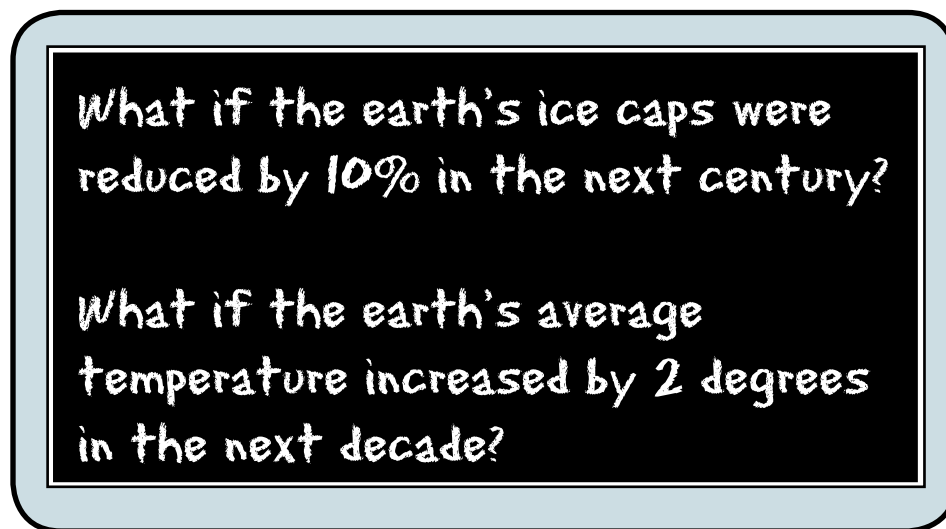

What if the earth's ice caps were reduced by 10% in the next century?

What if the earth's average temperature increased by 2 degrees in the next decade?

Figure 2.5. Examples of "What if…" questions a researcher may ask to try and understand earth system processes.

Experimenting with Computer Models

Materials

Computers to run the Radiation Balance Model. To use this model, you will need:

- ✓ A Windows (with any operating system including Win 95 or higher) or Apple PC.
- ✓ A web browser enabled with Java Version 1.3 or higher (Any Mac with OS X version 10.2 or better will include Java 1.3. Windows users may have to download and install the runtime version of Java at http://www.java.com/)
- ✓ The courseware (a Java applet) loaded into your web browser: available at http://icp.giss.nasa.gov/education/modules/eccm/model/ – see Education Tools, Earth Climate Course Computer Models for Module 1.

Methods

Preliminary Discussion and Preparation

1. Pose several hypotheses for what will happen if you continue heating or supplying energy to the hot and cold planet models.
2. At the computer, review model features and experiments by reading the Reference: Local Radiation Balance Model User Guide. (*See page 45.*)

Experimentation and Observation

1. Conduct Experiment 1. Complete Experiment 1 Data Sheet
2. Conduct Experiment 2. Complete Experiment 2 Data Sheet

Data Analysis and Consensus

1. Discuss the results of your modeling experiments and prepare a presentation.
2. Share results as to what happened to the model's temperature.
3. What can be inferred about energy radiating to and from our planet from the fact that temperature reaches equilibrium? Which fundamental law is associated with this condition?
4. How did the albedo of the model's surface affect its equilibrium temperature?
5. What was learned about the relationship between distance and temperature?
6. What is meant by the phrase "Energy Balance"?
7. Assess what you learned by completing the investigation Questions.

Investigation Notebook

1. Data Sheets: Experiments 1 and 2.
2. Questions: Using Mathematical Computer Models
3. Essay: Topic 2: Preparing for Mars Living in an Arctic Outpost

Introduction to the Local Radiation Balance Model

Study the radiation balance properties of an object exposed to a light source in a room by varying its albedo and distance with the Local Radiation Balance Computer Courseware Model.

The Local Radiation Balance Model simulates an experiment in which a object filled with some sort of material, and covered with a more or less reflecting surface, (supplying an albedo) is placed at a selected distance from an energy source. When the energy source is switched on, the student measures how the temperature of the object evolves with time. Parameters that can be adjusted are:
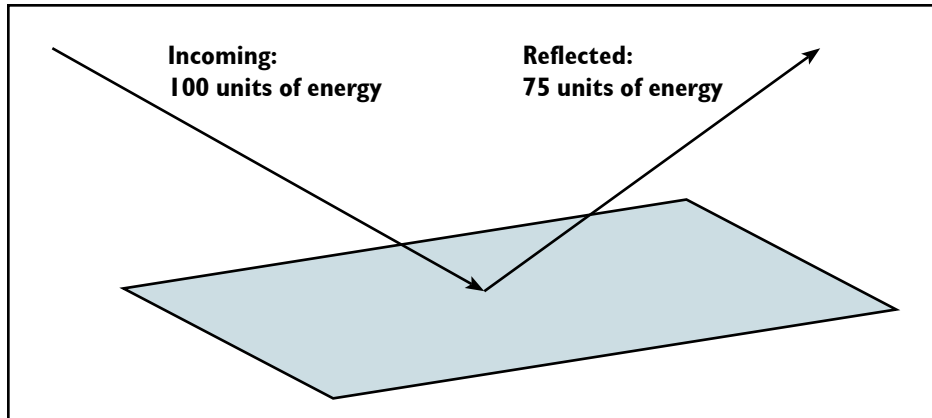
Figure 2.6. Albedo (from Latin albus, meaning white) is a term used to describe the ability of a surface to reflect energy. An object that reflects none of the energy hitting it has an albedo of 0 (or 0%), and would appear black. An object that reflects all of the energy hitting it has an albedo of 1 (or 100%), and would appear white. In the diagram above, 75 of the 100 units of energy are reflected, therefore the surface of the object has an albedo of 0.75 (or 75%.)

- The reflectivity (albedo) of the surface
- The distance between the energy source and the object
- The power of the energy source
- The ambient (or surrounding) temperature

Experiments

Three experiments can be performed using this computer model:

1. A quantitative study of the relationship between equilibrium temperature and the distance from the light source to the box, demonstrating the Inverse Square Law.
2. A quantitative study of the relationship between equilibrium temperature and the reflection coefficient (albedo) of the surface of the box.

Local Radiation Balance Model User Guide

The Local Radiation Balance Model contains three pages (or screens), each of which is described below. Use this guide to familiarize yourself with the features of the model, and as a reference during experimentation. To view the model, you will need to use a Windows or Apple PC and a monitor with a minimum 640 x 480 resolution and 256 colors. The model is available on the web at http://icp.giss.nasa.gov/education/modules/eccm/model/

Page 1

The first page of the model (The Plot Screen) is the page on which the experiments are performed and is shown in figure 2.7 below.

The red rays show the outgoing and incoming long wave energy between the object and the room.

The yellow rays indicate the short-wave energy that is received by and reflected by the object.

The room temperature, reflection coefficient, power of the source, and the distance are entered here..

See your experiment's log at any time by clicking on the Log button.

See a User Guide at anytime by clicking on the Help button.

Watch while a plot of your results is generated as the experiment proceeds.

Use these buttons to control the flow of your experiment.

Figure 2.7 Page 1 of the model.

The observation panel displays the variables as they change over time.

In the experimental control fields located in the lower left hand corner, the user is able to input the following values:

(1) the Room Temperature (in °C)
(2) the Reflection Coefficient (or albedo - a value between 0 and 1)
(3) the Power of the light source (in watts)
(4) the Distance between the source and the object. (in meters)

The user can then select whether the light source is on (for heating), or off (for cooling), and then start, stop or pause the experiment with the control buttons located in the lower right hand corner of this screen.

The resulting elapsed time, equilibrium temperature, the current temperature, and the input, output and absorbed powers of the object are displayed in the window located in the bottom center of this screen.

The user can select the other two pages (screens) by clicking on the "Log" and "Help" buttons at the top of this screen. Clicking on the "Plot" button will return the user to initial page.

Page 2

After completing experiments, you have the choice of reviewing your log for completed sessions from your experiment. The log is erased every time you begin a new set of experiments.

The Plot button returns you to the first screen.
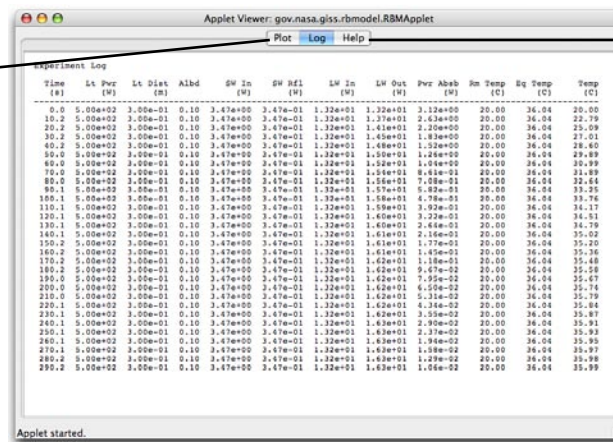
The Help button will bring up a User's Guide..

Figure 2.9. Page 2 of the model.

The data on this page can be highlighted and examined, but the present version of the applet does not allow the user to copy the data to the clipboard..

Page 3

A brief User Guide to the radiation balance model appears on page three and can be accessed by clicking the "Help" button on any page.
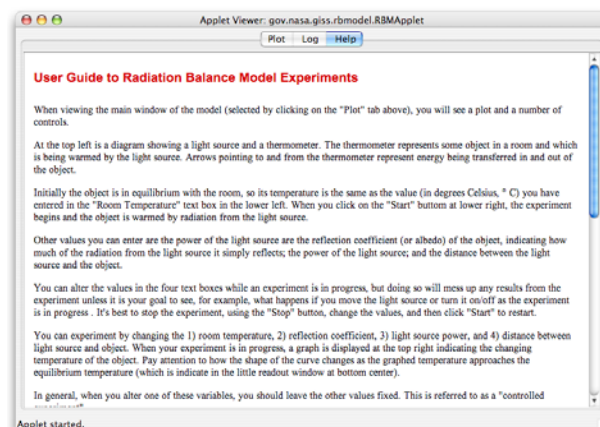
Figure 2.10. Page 3 of the model.

Experiment 1

Study the relationship between equilibrium temperature and the distance from the light source to the box.

1. Set room temperature to 20ºC and reflection coefficient to 0.
2. Make sure that the distance to light source is approximately 30 cm (0.30 m).
3. Click the "Light On" button.
4. Click the "Start" button.
5. Use the "Pause" button to suspend the experiment and look at the values of the various readings at any time. To unpause your experiment, click the "Continue" button.
6. Observe the graph that appears. Temperature (y-axis) is plotted versus Time (x-axis) since the light source was switched on. What happens as time progresses?

7. Observe the values for the different variables in the lower section of the screen. Has equilibrium temperature been reached? Compare the absorbed and outgoing power.

8. Continue timing until you think that equilibrium temperature has been achieved.
9. Click the "Stop" button.
10. Fill in the values for the four variables in the table below.
11. Repeat steps 3 through 10 with the distance set to approximately 60 cm and 90 cm. Do not change the room temperature or the reflection coefficient.
12. Note down values for the variables below.

distance (cm)	outgoing energy/sec	absorbed energy/sec	present temperature	equilibrium temperature
30				
60				
90				

Table 2.3. Results With Varying Distance and Room Temperature = 20ºC.

13. Now set room temperature to – 270ºC and the reflection coefficient to 0.
14. Repeat the experiment (steps 3 - 10) with the distance set to 30 cm, 60 cm, and 90 cm.
15. Note down the values for the variables in the table below.

distance (cm)	outgoing energy/sec	absorbed energy/sec	present temperature	equilibrium temperature
30				
60				
90				

Table 2.4. Results With Varying Distance and Room Temperature = – 270°C.

16. What effect did increasing the distance have on equilibrium temperature? Explain.

17. Was the change in the equilibrium temperature (and absorbed energy) proportional to the change in distance? Elaborate.

18. Did the change in absorbed energy obey the Inverse Square Law? Why/Why not?.

19. What is the significance of setting the ambient temperature to – 270°C?

20. Hypothesize as to how you might change this experiment to show the Inverse Square Law behavior.

21. In each case, how did the total energy arriving at the box compare with the energy emitted by it?

Experiment 2

Study the relationship between equilibrium temperature and the reflection coefficient of the surface of the box.

1. Set the reflection coefficient to 0.

2. Set the room temperature to 20°C.

3. Make sure that the distance to light source is approximately 30 cm (0.30 m).

4. Click the "Light On" button.

5. Click the "Start" button.

6. You can use the "Pause" button to suspend suspend the experiment and look at the values of the various parameters at any time. To unpause your experiment, click the "Continue" button.

7. Observe the graph that appears. Temperature (y-axis) is plotted versus Time (x-axis) since the light source was switched on. What happens as time progresses?

8. Observe the values for the different variables in the lower section of the screen. Has equilibrium temperature been reached? Compare the absorbed and outgoing power.

9. Continue the run until you think that equilibrium temperature has been achieved.

10. Click the "Stop" button.

11. Fill in the values for the four variables in the table on the following page.

12. Repeat steps 2 through 10 with the reflection coefficient set to 0.2, 0.4, 0.6, and 0.8. Be careful not to change the position of the box, the room temperature, or the power of the source.

13. Note down values for the variables at the end of each run in the table on the following page.

reflection coefficient	outgoing energy/sec	absorbed energy/sec	present temperature	equilibrium temperature
0				
0.2				
0.4				
0.6				
0.8				

Table 2.5. Results With Varying Distance and Room Temperature = – 270°C.

When you have completed the table above for the five different reflection coefficients and the corresponding values for other variables, answer the following questions on the basis of your results.

14. Did the equilibrium temperature increase or decrease as the coefficient increased? Why do you think this happens?

15. Was the power absorbed related directly to the reflection coefficient? Was the relationship linear or exponential between these two variables?

16. Was the equilibrium temperature simply related to the reflection coefficient? Was the relationship linear or exponential between these two variables?

17. Compare the response of the temperature to the reflection coefficient to the response of the power absorbed to the reflection coefficient.

18. What can you conclude from this experiment?

Experimenting with Computer Models

1. How would increasing the amount of water in the physical model influence the time needed to reach thermal equilibrium?

   a) It would take the same time.
   b) It would take longer.
   c) It would take shorter.
   d) Impossible to say without additional information.

2. Assume there are two planets with exactly the same characteristics, except that one is located far from the sun and the other close to the sun. The time for them to reach thermal equilibrium would:

   a) be the same.
   b) be longer for the planet close to the sun.
   c) be longer for the planet far from the sun.
   d) depend on the distance of the closer planet.

3. Which of the following planets reaches thermal equilibrium the fastest?
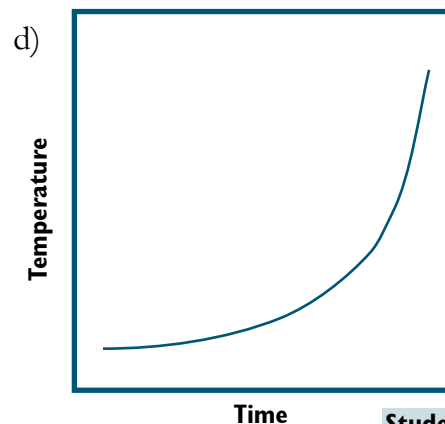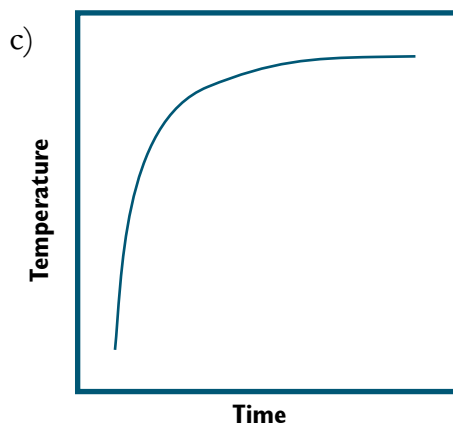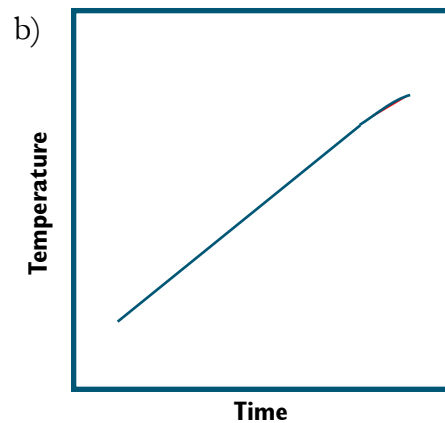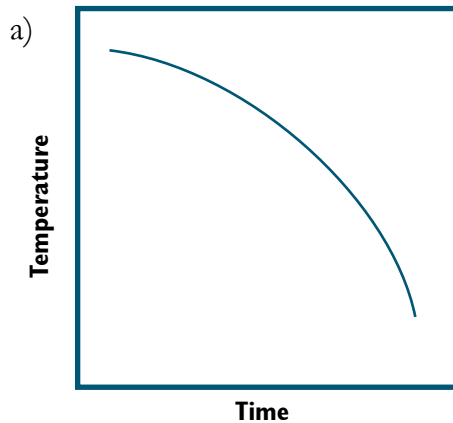
Approximating the Average Surface Temperature of the Earth

Overview

We have used a mathematical model, the Local Radiation Balance Model, to study some of the relationships that influence the temperature of an object when varying amounts of energy are supplied. This experiment simulated a planetary body and lead to assumptions about variables with the greatest effect on Earth's surface temperature. Scientists use far more complex computer models called General Circulation Models (GCMs) to simulate processes in a planetary system such as atmospheric circulation or wind patterns (e.g., the jet stream) and the ways solar radiation interacts with surface properties (e.g., the albedo or reflectivity of land and ocean). Just like the simple Local Radiation Balance Model, GCMs simulate earth processes using equations based on physical laws to determine a theoretical temperature for the surface of the earth.

What do you think is the earth's average surface temperature? How is it calculated? Since we have been talking about a global temperature for Earth, consider temperatures from all over the planet. How many temperatures do you need to use? This is a decision you must make as an investigator. You will need enough temperature values to get a relatively stable average. How many data elements or temperature values do you need to get a "good" average?

To understand the planetary temperature results produced by mathematical models, we need to ensure that we know (1) how to determine the actual average surface temperature of the earth, and (2) the value of that average. By computing the average, we can gain a scientific perspective on what happens in one part of the world and its impact on people in other regions and even throughout the world. This is why so many issues related to the environment are global concerns, and not only of interest to people locally or in a particular region.

Using an Internet web site, find temperatures from regions around the earth and calculate an average global temperature. A mathematical average will consider the sum of all data elements divided by the number of those elements. If you are using the Internet, one place to find this data is the USA Today website at www.usatoday.com/weather/forecast/wglobe.htm. Explore and record temperatures of locations around the world on the Data Sheet. Calculate an average global temperature using the USA Today web site or the Reference: Global Temperature Data.

Learning Objectives

- ✓ Utilize a data source from the Internet.
- ✓ Determine the average temperature of the earth.
- ✓ Specify the characteristics of a sampling necessary to achieve an accurate average.

Approximating the Average Surface Temperature of the Earth

Materials

Computer with access to the Internet. If you do not have Internet access, use the Reference: Global Temperature Data.

Methods

Exploration and Data Collection

1. Either using the USA Today website: www.usatoday.com/weather/forecast/wglobe.htm, or the Reference: Global Temperature Data, explore temperatures in regions around the globe.
2. Record temperature data for a minimum of 20 sites around the world on the Data Sheet for this activity. Be sure that your data points are representative of the entire surface of the planet.

Data Analysis, Comparisons and Consensus

1. Compare your results with other students in the class.
2. Answer the Questions for Activity C.

Investigation Notebook

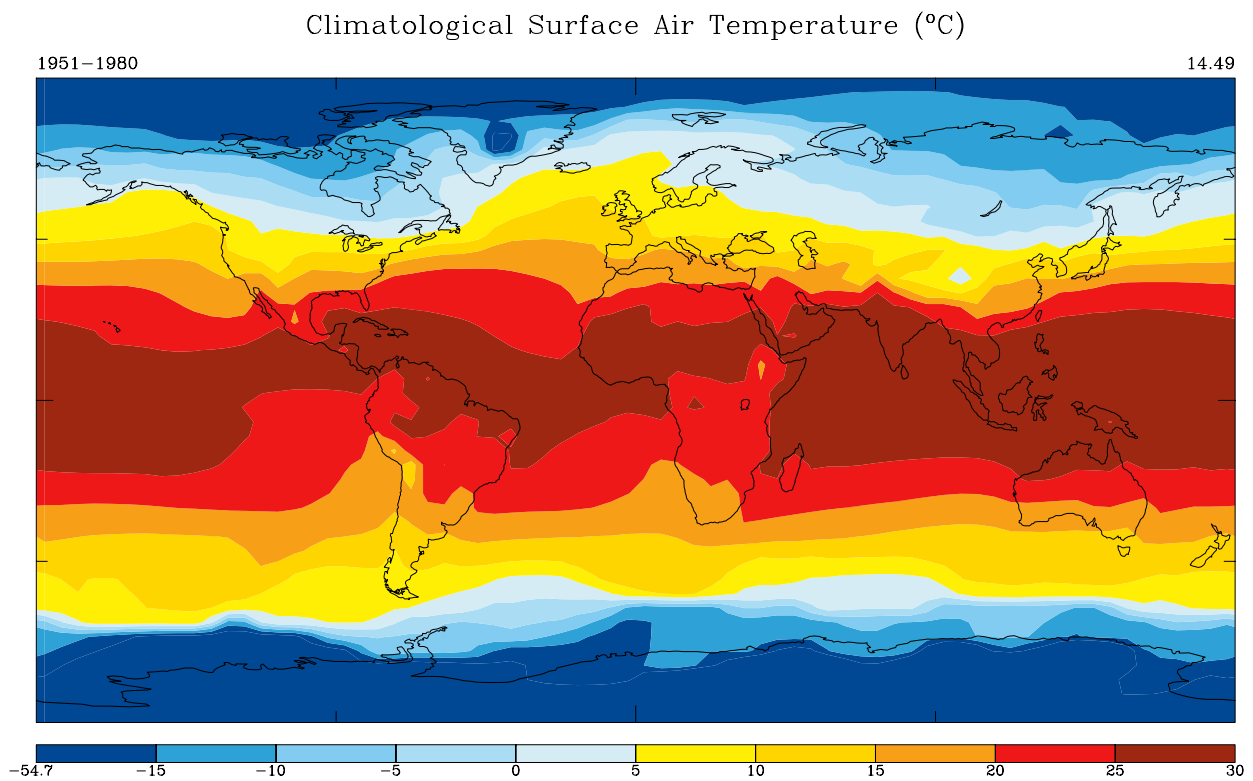Data Sheet: Approximating the Average Surface Temperature of the Earth
Questions: Approximating the Average Surface Temperature of the Earth

Approximating the Average Surface Temperature of the Earth

	Region/City	Temperature
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

Table 2.6. Sampling of data points for the surface of the earth.

Compute your average temperature global surface temperature:

Global Temperature Data

Figure 2.11. Average global surface temperature calculated for a 30-year period (1951-1980). Data source: Legates.

Approximating the Average Surface Temperature of the Earth

1. How can you ensure that you get adequate representation of all temperatures on Earth to get a reasonable estimate of its average temperature?

2. How many temperatures would you like to have in order to determine your average?

3. Calculate the average for 5, 10, 15, 20, etc., of your temperatures.

    (a) What happens to the average as you increase your number of samples?

    (b) What happens when only temperatures over land are used?

4. The accepted value for the average surface temperature of the Earth is _____ . (Ask your instructor for this value). How does your average value compare to this accepted value?

Write a 300 word essay that responds to the questions in this topic's Real World Problem (refer to page 22). Justify your response with supportive evidence from the modeling investigations you conducted, as well as what you learned computing the average surface temperature of Earth.